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COMMUNITY HAZARD VULNERABILITY ASSESSMENTS: HOW TECHNOLOGY CAN ASSIST IN COMPREHENSION

by

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COMMUNITY HAZARD VULNERABILITY ASSESSMENTS: HOW TECHNOLOGY CAN ASSIST IN COMPREHENSION

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ABSTRACT

The *Federal Disaster Mitigation Act* of 2000 mandates that all levels of government identify, classify and develop plans for the mitigation of the hazards to which they are exposed, be they natural or man-made. In addition to the legal requirement, communities need to complete a hazard vulnerability assessment to help them determine priorities in deciding how much of a given resource should be aimed at solving a given problem. No communities have unlimited resources; as such, it is imperative that resource allocators, be they emergency managers or elected officials, fully understand the depth and breadth of the multitude of hazards their communities face. Understanding how humans process information and then using technology to assist in the comprehension of that information can only enhance a community's emergency management cycle of planning, mitigation, preparedness, response and recovery.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALOHA	Area Locations of Hazardous Atmospheres
CAMEO	Computer Aided Management of Emergency Operations
HAZUS	Hazard United Stated
HAZUS-MH	Hazard U.S.–Mult-Hazard
IDLH	Immediately Dangerous to Life and Health
TLV	Threshold Limit Value
MARPLOT	Mapping Application for Response, Planning and Local Operational Tasks
NOAA	National Oceanographic and Aeronautics Administration
NPS	Naval Postgraduate School
SARA	Superfund Amendments and Reauthorization Act

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I. INTRODUCTION

A. PROBLEM STATEMENT

In order to be eligible for federal disaster grants or reimbursement funds, every community is expected to review their communities' emergency operations plans every two years. The foundation of an emergency operations plan, or for that matter, a disaster mitigation plan, is a community hazard vulnerability analysis. The purpose of such an analysis is to determine that for which a community should plan. Community leaders need to fully understand the myriad of vulnerabilities that apply to particular a community in order to reduce those vulnerabilities through mitigation efforts and emergency response plans. Especially in today's economy, communities are challenged in addressing the problems they face. Increasing costs for police protection, roadway maintenance, sanitation, library services, social services and recreation facilities strain the revenue streams. No community is blessed with unlimited resources to expend on all of the demands placed upon it; as such, priorities must be determined and resource allocation decisions should be, ideally, based upon those priorities.

Hazard vulnerability reports identify, assess, analyze and attempt to quantify the threats facing a community, providing a relationship between the probability of an event occurring and the consequences of that event. As such, the hazard vulnerability report is the foundation of the plans to prepare, mitigate, respond and recover from the various hazards. Since it is the underpinning of follow-up plans, it is imperative that the reports are presented to decision makers, such as elected officials, in a manner, or manners, that are easily understood.

Many community hazard vulnerability reports consist of written documents distributed to those decision makers who need to study it to ascertain community threats; however, narrative documents may not be the most efficient method transferring information to a decision maker. Written narrative can be time consuming to read. Bell (2001) reports that the average reader is capable of reading and comprehending 230–250 words per minute in a text format. A double-spaced report with a 12-point font will

produce approximately 250 words per page (Waters, 2010). Couple that with Bell's findings, and it results in about one minute reading time per page of narrative. A narrative report that is 120 pages in length will take about two hours to read; as such, it is a time-intensive method of information transfer (Waters, 2010).

Individuals have different learning styles, including visual or spatial, verbal or linguistic, auditory, kinesthetic and mathematical or logical.[1] Edgerly (2010) explained the consequences of ignoring these differences when he wrote, "A learner who's forced to learn in a manner they're not comfortable with [sic] may produce less-than-satisfactory results" (p. 20). Emergency managers, and elected officials who support them, cannot afford to make resource allocation decisions that contain even a modicum of ambiguity in the presentation of the data within an assessment. Emergency managers must determine priorities by comprehending the magnitude of a given threat and comparing it to the other threats that face the community. As such, it is important that the vast amount of information contained in a hazard vulnerability assessment report be assimilated and understood in order to be evaluated by such decision makers. Assessments should be presented in a manner optimal for transferring information to those who need to use it. Through integration of various media, including text, audio, and video, material can be presented in a manner that better matches the learning styles of individuals within the emergency management community.

Methods need to be developed to get the hazard vulnerability information into the psyche of the emergency management community, into their very thought processes. To expand, when a hazard vulnerability assessment is completed, it is not the end of the work. Those responsible for preparation, mitigation, response and recovery, the professional staff, must evaluate the best method, or methods, to get the information across to the decision makers, the elected officials who control the funding; choosing multiple presentation mode must be inherent in the entire process. Written hazard vulnerability analysis reports commonly use text as the media and are constructed as narratives. Many of these reports, especially in small communities with limited resources,

[1] These concepts will be explored later in this thesis.

do not take advantage of other types of media such as images, video and animation that are better matched to particular learning styles and may result in increased information assimilation among emergency managers who utilize those learning styles.

In 2010, this author conducted research on community hazard vulnerability assessments in four counties in southeastern Pennsylvania. The original purpose of that research was to compare methodologies used for hazard vulnerability assessments, focusing on data collection and analysis. In addition to the data collection and analysis, the research revealed that narrative assessments may not be the preferred presentation model for enhanced understanding of the information presented. The research also indicated that this could result in a loss of effective and efficient assimilation of information of the assessments (Waters, 2010).

In addition to sub-optimal assimilation of information, the template used for the collection of data, the currency of the data and the method in which the data was presented contributed to the overall efficacy of the reports. Comparing the reports, a lack of consistency was evident. This can be a problem when, for instance, a county emergency management agency must read and act on multiple reports from municipalities within it.

For example, Montgomery County, Pennsylvania consists of 62 independent political entities, each with their own set of elected officials. The county emergency management agency must coordinate the actions of each of those municipalities, each having written its own respective hazard vulnerability report. Without some sense of consistency in the reports, it is difficult for the county to compare each community's risks. In addition, two of the reports were of such age as to make the value of the information contained therein questionable. The presentation of the data also differed among the reports. The method of presentation of a community hazard vulnerability report needs to be studied to assure that the presentation methods match an individual's learning style. By customizing presentation methods to the individual learning styles of the emergency management decision makers, it can be assured that those decision makers accurately understand the threats that face a community and take appropriate steps to address those threats.

B. RESEARCH QUESTIONS

1. What is the purpose of a community hazard vulnerability assessment report?
2. What is the role of learning styles in moderating/influencing the assimilation of community hazard vulnerability assessment reports?
3. How can technology be leveraged to increase community hazard vulnerability assessment assimilation effectiveness?

C. SIGNIFICANCE OF THE RESEARCH

Upper Merion Township and Montgomery County, Pennsylvania, and for that matter, any community, can use this research to help build and maintain a robust and dynamic hazard vulnerability information system that better matches learning styles to media type in seeking to enhance comprehension. In addition, the emergency management community can use this research to develop a template to facilitate consistency in hazard vulnerability assessments to not only address that which should be studied, but also the manner in which it is be presented and the technology that can be used to enhance the assessments' value.

II. LITERATURE REVIEW

The literature review concentrated on three different areas:

1. why communities should conduct a hazard mitigation assessment,
2. how humans process information and
3. what technologies are available to help communities process the data compiled in their hazard mitigation efforts into actionable decisions.

A. WHY COMMUNITIES SHOULD CONDUCT A HAZARD MITIGATION ASSESSMENT

A review of the literature shows that the *Federal Disaster Mitigation Act* of 2000 mandates that all levels of government identify, classify and develop plans for the mitigation of the hazards to which they are exposed, be they natural or man-made. Unfortunately, there is limited written guidance on how to accomplish this feat. The Pennsylvania Emergency Management Agency expects such assessments be completed every five years, but there is no statutory force behind this expectation. Bellavita (2010) and Boniface (n.d.) touch upon the purpose of hazard vulnerability assessments, basing emergency management decisions on risk, but this concept must be communicated to those decision makers in a manner that allows complete understanding. In addition, communities' risk may change over the years and, even if the governmental entities complete a plan, if it simply languishes on a shelf, or if the method utilized to present the plan does not get the message across, money can be wasted, mitigation strategies misdirected, response plans ineffective and people hurt or killed. As such, the presentation of the plan is as important as the information in the plan.

B. HOW HUMANS PROCESS INFORMATION

People process raw data through their brain functions, hopefully, changing those raw facts into useful information. As such, it is important to understand how the brain works.

Nixon (2004) described the how the different hemispheres in the human brain process information. His work can be synthesized into Table 1.

Table 1. Findings of Nixon (After Nixon, 2004, p. 35)

Left Side Brain		Right Side Brain	
Verbal	-uses words	Nonverbal	-little connection with words
Analytic	-goes step by step	Synthetic	-pieces for a whole
Symbolic	-symbols represent things	Concrete	-relates to present
Abstract	-small pieces represent whole	Analogic	-sees similarities
Temporal	-keeps track of time	Nontemporal	-no sense of time
Rational	-conclusions based on fact	Nonrational	-not requiring reason
Digital	-uses numbers	Spatial	-uses relationships
Logical	-conclusions based on logic	Intuitive	-conclusions based on gut
Linear	-links concepts	Holistic	-sees larger picture

Nixon identified three of those processes: 1) visual, 2) auditory and 3) kinesthetic (2004). He felt that "By understanding how information is processed and knowing about various learning preferences, you can modify your presentation to best suit the needs of the group and enhance learning" (Nixon, p. 34).

This last statement is critical, as this means that vulnerability assessments, when presented as learning tools, must be delivered in such manners, plural, as to meet the needs of the decision makers. If not, resource allocations to address vulnerabilities may be squandered on the wrong, or less important, problems. To ensure that information is truly understood, data should be presented in a manner in which information is readily perceived and assimilated by individuals. A written report may not be preferred by those who perceive information visually. They may read lists of addresses of the locations of

hazard and another list of addresses daycare centers, but if a reader does not, or cannot, understand the relationship between the two lists, the information may be of limited value.

In reviewing how information can be presented to decision makers, the literature indicates that much has been done regarding learning and learning styles. For instance, Kolb (1985) created the learning style inventory, classifying how different individuals prefer different presentation modes in order to learn. Work has been done studying the continuum of learning from the simple remembrance of data presented, known as knowledge, to evaluation, being able to classify and create a hierarchy of that knowledge, termed Bloom's taxonomy and to make decisions regarding priorities based on that information.

Campau (1998) and Duncan (n.d.) supported Kolb's work in studying how the emergency medical community learns. They also recommend the further study of learning and learning styles as a method to more efficiently have students assimilate information (Campau & Duncan), as did Criss (2002) in the *Journal of Emergency Medical Service*.

In the fire and police arena, Rostan (2003) detailed the impact on learning styles one the telecommunicators (dispatchers) who interact on an ongoing basis with our various emergency responders. In addition, Schofield (2012) explored the role of graphics when presenting evidence in the courtroom.

The European industrial community was exposed to the concept of learning styles by Sadler-Smith (2003), so it is obvious that this is an area of global study. Yet, not all are convinced this theory is valid. Yang Su (2011) questioned its legitimacy, stating "there is little scientific evidence to support the learning styles theory" (p. 1). Ambiguously, she states, "nonetheless that a diverse range of teaching styles was needed to clearly convey information" (p. 2).

The literature also reveals studies regarding information richness, the ability of the method of presentation to allow more enhanced understanding of the data presented. The more richly information is presented, the more of it is assimilated by the consumer.

Daft and Lengel studied the concept of information richness in 1984 and again in 1986 when they addressed the topic of presenting information to organizations. Bergin revisited the topic of information richness and its impact on learning in 2010.

It is important to study how technology can be used to better match various forms of media to the learning styles of the intended audience. Spatial awareness, the importance of the relationship of data, is paramount and geographic information technologies permit the seamless integration of various data in a visual format. Harrison, Gil-Garcia, Pardo and Thompson, (2006) stated:

> Of the various waves of technology development that has diffused widely over the last three decades, among the most exciting have been the tools that use or generate geo-spatial data, that is, data providing location information in which a common spatial coordinate system is the primary means of reference.

In an article concerning the monitoring of environmental systems, Gross (2003) mentions the spatial component. He states, "Diagrams are usually necessary to communicate links between ecosystem components and to illustrate interactions between components, especially when spatial context is important" (Gross, p. 6). He also feels that "In some cases, the process of developing models is more important than the actual model" (p. 2). Feld, Nemitz and Hering (2009) also wrote an article concerning the environment; in it they define a conceptual model as "…a map of entities (concepts) and their relationships" (p. 4). From environmental concerns to hazard vulnerability assessments, the statements hold true in both arenas.

Studies have found that for those who prefer a visual type learning style, and those who are new at a subject matter, comprehended the information better when illustrations were included in the presentation. Ollerenshaw, Adiman and Kidd (1997) analyzed this matter and found that illustrations and, using new technology, computerization programs that presented information using "visual stimuli" increased the comprehension of the user.

Fitzgerald (2003) found "Participants who learned using their strongly preferred learning style improved the most from pretest to posttest" (p. 105). In addition, he states,

“Overall, the results of this study supported the hypothesis that matching the type of activity…to the learner’s preferred learning style improved performance” (p. 111).

The research seems to demonstrate that how brain process information results in the concept of learning styles. Learning styles are formed by mixing how one perceives new information and how that information is processed. Some like to read narrative, some prefer to see information presented with graphics; some prefer a hands-on experience and others would rather have an instructor who demonstrates an action prior to the student attempting it.

In the homeland security arena, information presentation should match the learning style of the information consumer, this consumer being the emergency management community. Yet, it appears authors of hazard vulnerability assessments often distribute information using only one learning style, such as hard copy reports, to convey information that represents the needs of one type of learner but may not be an effective means of those who tend towards other learning styles. Twenty-first century technologies enable continuous updates to plans, mass customization and the presentation of information in a format that best matches the learning styles of those who are consuming the information.

Those who are visual learners (show me) prefer to see or watch charts, graphs, pictures and videos to gain information about a given subject. The use of graphics and animated or real videos could enhance their ability to understand the information presented. For instance, note Figures 1 and 2; one depicts a number of threats in tabular form; the other displays the same information in graphic form.

	Police	Fire Companies	Emergency Management		Average
Transportation Incidents	9	7.5	3	Transportation Incidents	*6.5*
Flooding	4	3	6	Flooding	*4.3*
Fires	6	4	6	Fires	*5.3*
Winter Storms	6	3	6	Winter Storms	*5.0*
Tropical / Wind Storms & Tornadoes	4	4.5	6	Tropical / Wind Storms & Tornadoes	*4.8*
Hazardous Materials Incidents	4	3.5	2	Hazardous Materials Incidents	3.2
Geological Incidents	4	1	1	Geological Incidents	2.0
Nuclear Facility Incidents	1	1	1	Nuclear Facility Incidents	1.0
Dam Failures	1	1.5	6	Dam Failures	2.8
Terrorism	2	3.5	3	Terrorism	2.8
Riots	4	1.5	1	Riots	2.2
Drought / Water Supply Emergencies	2	2.5	1	Drought / Water Supply Emergencies	1.8
Energy Emergencies	4	4.5	4	Energy Emergencies	*4.2*
				Average	3.5

Figure 1. Tabular Representation of Vulnerabilities (From Upper Merion Township, 2010)

The information displayed in Figure 1 may be preferred by those are auditory learners. They will study the numbers and determine the threat posed by each type of event. Color coding enhances the differences between the higher and lower calculated threat.

On the other hand, visual learners would likely prefer Figure 2.

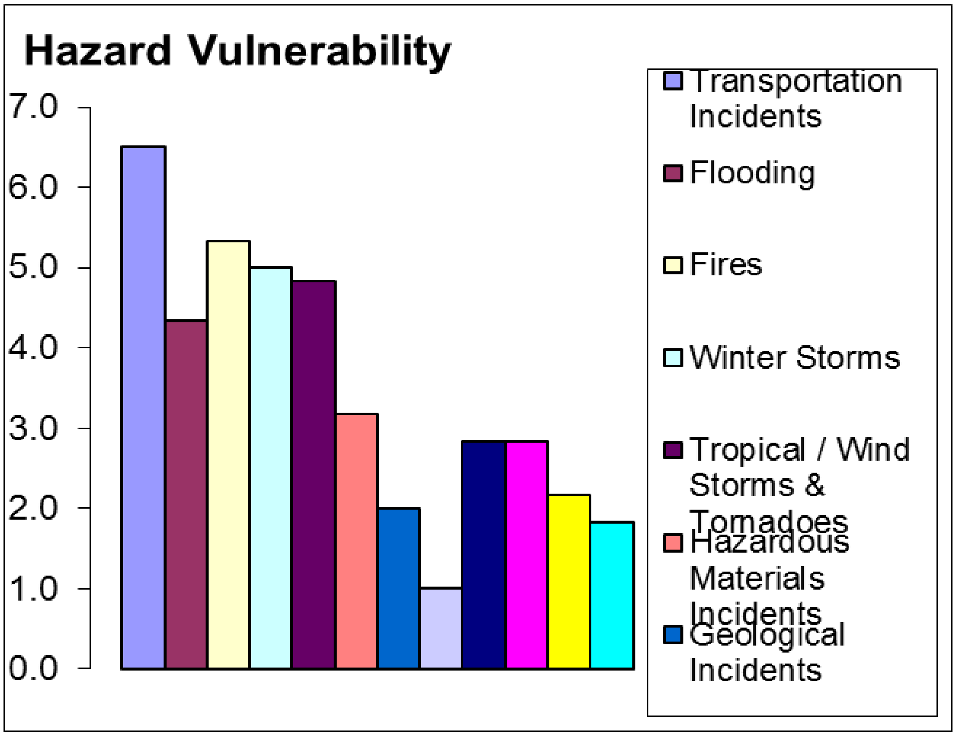

Figure 2. Graphic Representation of Vulnerabilities (From Upper Merion Township, 2010)

The information displayed is the almost identical; however, the visual learner can clearly see the results and their relationships without having to analyze any numbers; that said, the mathematical learner can still analyze the numbers, if so desired.

Auditory learners (tell me) prefer formal lectures, a verbal means of communication. Written reports may well be a type of auditory presentation, as readers may hear the words as they read them, but more research is needed in this area of study. The use of a "books-on-tape" format, recording the written word for later listening, may enhance the comprehension of a vulnerability assessment. Furthermore, kinesthetic learners want to move physically to learn. Permitting them to use technology to manipulate a simulation or to enter data into a model enhances their interest in information, as well as their comprehension.

Daft and Lengel (1986) state, "One challenge facing organizations is to develop information-processing mechanisms capable of coping with variety, uncertainty, coordination, and an unclear environment" (p. 555). Daft & Lengel also explain:

> Media differ markedly in their capacity to convey information. Just as the physical characteristics of a pipeline limit the kind and amount of liquid that can be pumped through, the physical characteristics of a medium limit the kind and amount of information that can be conveyed. (Lengel & Daft, 1984, p. 226)

Media richness reaches from high to low; matching media richness with learning styles when presenting community hazard vulnerability assessments will enhance the comprehension of the information contained therein.

According to Bergin (2010):

> Media richness may be considered as a contingency factor that is selected based on the task environment, the task itself, or the social influences within or among organizations. Many organizations select and use media to enhance or enable individual decision making performance. (p. 8)

The purpose of a community hazard vulnerability assessment is to provide information on which to base decision making regarding resource allocation. The topic of media richness, then, is of importance to the emergency management community as the media used to provide information is as important as the information itself.

According to Daft and Lengel (1986), the characteristics that establish the "richness" of a medium include:

1. the ability to send multiple signals at the same time,
2. the ability for the learner to provide timely feedback and
3. the ability to connect with the learner on a personal basis.

Face-to-face communication is considered the highest in media richness. Verbal cues, such as the tone, pitch or volume of voice, convey information that is lacking in a written report. In addition, non-verbal cues, body language, are obvious during one-on-one conversations.

Telephone calls, while including cues such as tone of voice, cannot express the non-verbal cues of body language and, as such, are not as rich a communication medium as face-to-face contact. Both, however, offer the learner with the opportunity to provide immediate feedback through the ability to ask questions. In addition, both types of interactions are personal in nature.

Written personal memos, while archive able, transfer information, are fairly time consuming as it relates to feedback. Obviously, there is no non-verbal exchange of information, but such media do provide a limited amount of personal connection, as such memos or documents are addressed directly to the reader and the reader alone.

Formal memos, on the other hand, while sharing some of the advantages and disadvantages of personal memos, lack any personal connection. Moreover, tables showing simply numbers appear to be the lowest on the richness scale for they lack any of the characteristics for effective communications. On the other hand, Nixon (2004) looked in a different direction; he felt that it was important to study how the brain processes information and from that knowledge, methods of presentation to best take advantage of an individual’s preference: logical or emotional.

C. WHAT TECHNOLOGIES ARE AVAILABLE TO HELP COMMUNITIES PROCESS THE DATA COMPILED IN THEIR HAZARD MITIGATION EFFORTS INTO ACTIONABLE DECISIONS

Boyd, Dowling and Grantz (2009) explored the concept of information overload and how technology can be utilized to present information in a more concise form. Furthermore, Hansen (n.d.) found that many people prefer graphics in addition to narrative for the conveyance of information. The topic of technology is exceedingly dynamic, changing by the week and possibly even by the day. The literature is full of articles, books and videos regarding technology, its present state and its future uses. Technology is only limited by the imagination of those who work with it and write its code.

Three such technologies, which linked to geographic information systems were explored: 1) computer aided management of emergency operations, 2) Hazard U.S., and 3) The Infrastructure Consequence Flood Inundation Tool-2D. Weaver (2001) demonstrated how such systems can be used to enhance public safety. Other authors, Snider and Jover (1991) and Schellenberger (2003) explained the use of software program called Computer Aided Management of Emergency Operation and how it could be used to enhance assessments of hazardous materials vulnerabilities.

Vickery, Lin, Skerlj, Twisdale and Huang (2006) delved into the use of storm modeling, linking it to community census tract data, to predict life and property loss during natural disasters. Larson, DelValle, Ambrosiano and McPherson (2011) took the modeling concept one step further, using it to predict the impact on local health-care systems in the event of a major flood.

Unfortunately, the literature regarding the links between learning, learning styles, technology and community hazard vulnerability assessments is weak. Further research is needed in this arena.

III. METHOD

To answer the first question: what is the purpose of community hazard vulnerability assessment report; an analysis of literature was performed to determine why communities develop them. Are there statutory requirements; if so, who promulgates them? What is their end-purpose; how will this information be used; is there a relationship between community hazard vulnerability assessments and other reports? A review of the literature was used to explore how existing community hazard vulnerability assessment reports are filed currently; how often are they required to be updated; what are the current guidelines for composing such reports; and what are the weaknesses in the existing protocols. In addition, a review of the literature was conducted to better understand what factors/enablers make community vulnerability reports useful (timeliness, objectivity, relationship among information, etc.).

To answer the question: what is the role of learning styles in moderating/influencing the assimilation of community hazard vulnerability assessment reports, an analysis of literature was performed to understand how the brain processes information, learning styles and if there is a difference in the absorption of information depending upon how that information is presented.

Lastly, concerning how technology can be leveraged to increase community vulnerability assessment assimilation effectiveness, several relevant examples were identified from the literature in which technology was a contributor to the understanding of emergency management information. Analysis was then conducted to determine what technology is available to: 1) determine community vulnerabilities and, 2) to present that information to the emergency management community, taking into account the findings regarding learning styles. Four technologies (Geographic Information Systems (GIS), Computer aided management of emergency operations (CAMEO), Hazard U.S. (HAZUS), and the Infrastructure Consequence Flood Inundation Tool 2-D) were then utilized to explore exactly how the data could be displayed. These technologies were selected due to their ability to provide for graphic representations of a number of issues of which an emergency manager might base resource allocations decisions. By analyzing

this information and matching those results with information gleaned from the study of the technology, a model was developed depicting methods, and possibly software, that could be used by emergency management professionals to enhance comprehension of the threats that loom over a community.

IV. ANALYSIS AND FINDINGS

A. WHAT IS THE PURPOSE OF A COMMUNITY HAZARD VULNERABILITY REPORT?

The *Federal Disaster Mitigation Act* of 2000 requires each state and local jurisdiction to "identify the natural hazards, risk and vulnerabilities" to which the jurisdictions are exposed (p. 8). The starting point for a mitigation plan is the hazard vulnerability assessment. According to Beckman and Simpson (2006), the failure to develop such plans may be used to deny federal grant funding to assist communities in developing mitigation and response plans. While there are federal rules regarding disaster planning, they are administered by the states. For example, in Pennsylvania, there are no requirements for the updating of a community hazard vulnerability assessment as part of the penning of a disaster mitigation plan. If the vulnerability assessment is out-of-date, any plans which use it is as a basis will, by default, also be out-of-date.

The Pennsylvania Emergency Management Agency (PEMA) recommends that such analysis be conducted every five years, but there is no regulatory requirement that forces it. In addition, PEMA has no written guidelines for conducting such analysis. Clearly, there is a need to provide information to those who must write such reports as to just what they need to contain, how often they should be reviewed and how they should be presented.

The purpose of risk-based decision making was stated by Lieutenant (Lt.) Duane Boniface (n.d.) of the United Stated Coast Guard when he wrote:

> Risk-based decision making provides a process to ensure that optimal decisions, consistent with the goals and perceptions of those involved are reached. This process ensures that all available information is considered and used as appropriate to the decision at hand. (p. 1)

Bellavita (2010) of the Naval Postgraduate Schools Center for Homeland Defense and Security asked, "Both the Bush and Obama administrations agree that homeland

security decisions—especially resource allocation decisions—should be risk-based…but how does one determine their relative risk and their vulnerability to major events, be they terror attacks or natural disasters?"

Interestingly, Bellavita (2010) went on to question whether this process actually "ensures" anything, stating:

> Despite the best efforts of numerous experts from government industry and academia, fully effective and transparent integration of risk assessments into…homeland resource allocation decision-making remains an elusive goal…the risk construct… [Risk = Threat x Vulnerability x Consequences] is logical, intuitively appealing and consistent with conceptualizations of risk used in other domains. (p. 4)

He appears to suggest that, although the risk construct sounds good, it may not be the total answer and that there may be other factors other than threat, vulnerability and consequence. Such factors might include the perception of the threat or the influence of politics on the decision-making process regarding risk. The perception of threat and the influence of politics are beyond the scope of this paper; further research could explore these factors in greater detail.

Communities are ever-changing and, as such, hazard vulnerability assessment reports will enable the decision makers to determine resource-allocation judgments only when these reports are accurate, timely, well-presented and well-understood. These reports must clearly demonstrate the relationship between the threats and that which is threatened; they must be as dynamic as the community on which it reports and, the research seems to show, be presented in numerous formats to assure the understanding of their contents to the audiences at which they are aimed. This "numerous formats" concept is explored in the next section.

B. WHAT IS THE ROLE OF LEARNING STYLES IN MODERATING/INFLUENCING THE ASSIMILATION OF COMMUNITY HAZARD VULNERABILITY ASSESSMENT REPORTS?

Hazard vulnerability assessments must be well understood in order to facilitate good decision making. It is imperative that those decision makers assimilate vast amounts of information regarding the threats that face their community. As such, the influence of

learning styles on the comprehension of information must be considered by those who are compiling and presenting a community hazard vulnerability reports.

Sadler-Smith (1996) defined learning style as "…a distinctive and habitual manner in acquiring knowledge, skills or attitudes through study or experience" (p. 31). By determining the influence of learning styles on the comprehension of information and discovering the technology that best suits those learning styles, a model can be developed for the presentation of hazard vulnerability assessments to the emergency management practitioner. Planning is an integral part of the emergency management system. As such, in addition to leveraging technology to enhance comprehension of assessments, technology can boost the value of the planning information by assuring that changes in the community are timely and accurately reflected in its hazard analysis.

Homeland security leaders should base their resource allocation decisions and legislative mitigation actions on hazard vulnerability analysis, threat assessments and natural hazard mitigation reports. These reports are time sensitive; as a community changes through development, so do the hazards that face it. A report that describes a threat (e.g., a chemical plant) that is no longer present, or worse, cannot describe a new threat that becomes apparent after the report was written, lessens its validity and, therefore, the value of the report. As such, hazard vulnerability reports and assessments must be dynamic, changing as a community changes.

Data, which is converted into information, must be current, comparative and presented as information using formats that are best matched to the learning styles of its users. Printed documents meant to convey information have a number of drawbacks, the most critical of which is age; if the data is dynamic, then as a written document ages, the information therein contained becomes less valuable. Brand (2010) echoed this sentiment, writing about a comprehensive map for the Soil Reference and Information Center in Ultrecht, the Netherlands:

> Because these maps live online in digital form, they will improve over time rather than becoming obsolete, as printed maps do. (As I saw happen with a California Water Atlas I instigated in 1979 while working for Governor Jerry Brown; the maps and diagrams in our book helped the state for only a few years.). (p. 278)

In other words, information regarding hazards and vulnerabilities must be kept current or its usefulness decreases over time. For example, in Delaware County, Pennsylvania, a community hazard vulnerability assessment, completed but not updated since 1982, referenced a chemical plant that was no longer in operation and a proposed interstate highway that was completed in 1991 (Waters, 2010). Resource allocation decisions based upon old data would result in planning for a fixed-site hazardous materials event, instead of a transportation-related hazardous materials event. For instance, this could entail the development of evacuation plans for a threat that no longer exists while ignoring the dynamics of a toxic spill on the highway.

Hazard vulnerability analysis, threat assessments and similar reports can be maintained electronically. Computer applications can then be used to leverage various presentation technologies to customize the method in which information is relayed to the mirror the users' learning styles. Understanding learning styles and coupling them with the method in which information is best understood could result in a better comprehension of the relationships between risk and that which is threatened.

Many groups read vulnerability assessments, and many of these assessment reports are simple, yet lengthy, written documents. Elected officials, administrators, executives, field personnel and their supervisors make decisions based on these narratives; however, what if the written report is not the best method of transferring information to some? Perhaps such reports could be presented in a number of formats and then an individual could choose the format with which they feel most comfortable. Such technologies could include geographic information systems, which graphically depict spatial relationships, and modeling software, which provides a method for predicting consequences of events prior to their occurrence.

This exploration into community hazard vulnerability assessment hopes to provide insights into how learning styles, media and technology enabler the influence the comprehension of community hazard vulnerability assessment data This envisioning process will allow the hazard vulnerability assessment writer to develop differing presentational modes that match the learning styles of the various audiences to enhance

the comprehension and, therefore, as the research indicates, enhance the decision-making results.

Although not specifically addressing "learning styles," it is also important to understand the levels of learning a person experiences that differing learning styles might enhance. In 1994, Anderson, Sosniak and Rehage reviewed the classification of learning levels in adults, which was developed by a group of experts in the teaching and learning fields. The result of their efforts became known as "Bloom's taxonomy" and resulted in "six major classes [of educational behavior]: 1) knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis, [and] 6) evaluation" (Anderson, Sosniak, & Rehage, 1994, p. 15). Knowledge, the first step in Bloom's taxonomy, is about simply remembering facts and figures as presented. Comprehension, the next level, represents "the understanding of the literal message contained in a communication" (Anderson et al., 1994, p. 19). Progressing in the continuum of the taxonomy, application is the ability to use the information after remembering and understanding its meaning. The following level, analysis, is the ability to understand the relationships between and among the varied presented information. Synthesis is the level at which a clear picture of the overall subject is realized and evaluation, the highest level of classification, is the point at which decisions regarding priorities can be made. The users of community hazard vulnerability assessment reports must remember the information presented in the reports, understand and analyze that information, see the "big picture" regarding their community's vulnerabilities and be able to evaluate that information for the purposes of priority-setting and resource allocation. Individuals must travel through the educational behavior classifications in their attempt to reach the highest level, that of evaluation, for their jobs are to appraise the various hazard threats to determine priorities in mitigating those threats.

The processes through which humans assimilate information have been chronicled extensively. Kolb (1985) published his treatise on learning styles that formed the foundation for follow-on research. Campau (1998) and Duncan (n.d.) support Kolb's work; both felt the findings were still valid and, in addition, that the differences in the manner in which individuals learn was disquieting. The research indicates that these

differences should dictate the use of various media to convey the information regarding a community hazard vulnerability assessment. In addition, Wilson added to this body of work in 2000 by identifying five theories concerning the manner by which individuals learn. Rostan (2003) identified two additional classifications of learning styles: 1) logical or mathematical and 2) verbal or linguistic. He describes the learning styles as the name implies, auditory learners prefer to hear the material presented. Furthermore, some can retain information after hearing it only once. Visual or spatial learners prefer to see information presented in graphical mode. Map, charts and pictures enhance their ability to retain information. In contrast, logical or mathematical learners want to be queried about the information presented. Their minds lock the information into the brain when they are forced to think about it through questioning. Finally, kinesthetic learners need to move their bodies to process information. Rostan (2003) provides the examples of pianists and dancers who exemplify kinesthetic learners Nixon (2004) studied brain activity, reporting on how each side of the brain comprehends and manages information. Along similar lines, Daft and Lengel (1986) developed a scale for information richness and explored the role of information richness in information assimilation and evaluation.

The manner in which people assimilate information is a complex subject, but Criss (2002) declared simply, “Different people learn in different ways” (p. 61). Emergency responders read reports every day; providing alternative methods of conveying information in order to enhance comprehension may be as important as the information itself.

Edgerly (2010) stated, “A learner who is forced to learn in a manner they’re not comfortable with [sic] may produce less than satisfactory results” (p. 26). In the emergency management field every effort should be expended to assure that our decisions are not “less than satisfactory,” as in many cases lives and property depends on our understanding the problem and determining a solution.

One of the ongoing discussions in the field that has yet to be definitively decided is whether reading is an auditory or visual skill. Some are of the opinion that the act of reading is visually oriented, other feel it is auditory (i.e., we hear ourselves read the

words). Yet other groups opine it is a combination of the two. Further research appears to be needed to settle these differences.

Klingensmith (2006) adds to the work of Rostan, stating, “Acquiring knowledge occurs in different ways and at different rates for different individuals” (p. 36). In in addition to the visual, aural, read/write and kinesthetic styles, in her study she adds “multimodal,” those who have multiple preferences (Klingensmith).

Kolb (1985) saw the learning method differently; he presented research that divided individuals into four different styles of learning processes: converger, diverger, assimilator and accommodator.

The converger is an individual who prefers to think about an action and then try it, to mentally analyze or picture the action steps and then actually taking them. His or her strengths include deductive reasoning and the practical use of the skill learned. This person, as a left-brainer, is a good decision-maker.

On the other hand, the diverger is an individual who prefers to connect emotionally with an action by watching the action to learn about it. This person, as a right-brainer, likes to be engaged with people and is creative. His or her strengths include sensitivity to the feelings of others.

Another type of learner, the assimilator, is an individual who prefers to think about an action by watching the action and learning about it. His or her strengths include deductive reasoning. This person likes theoretical processes as opposed to people-oriented connections.

Kolb’s final type is the accommodator, an individual who prefers to connect emotionally with an action and then learns from doing it. His or her strengths are that of action and is open to new ideas. He or she makes decisions from the “gut.”

Kolb’s four learning styles, as opposed to modes, can be revealed by individuals by taking a simple, 12-question assessment with the respondent “…to rank order four possible responses for each item” (Campeau, 1998, p. 48). Campeau further reports that this learning style inventory “…has been shown to be very reliable over time” (p. 48).

According to Campaeu (1998), Kolb "…synthesized an experiential learning model that consists of four learning modes: 1) concrete experience (CE); 2) abstract conceptualization (AC); 3) reflective observation (RO); and 4) active experimentation" (p. 48). These modes can be further described as CE-feeling, AC-thinking, RO-watching, and AE-doing.

Duncan (n.d.) has his own terms for these styles: Converger = devil's advocate learner, diverger = social comfort learner, accommodator = hands-on learner and assimilator = fact-oriented learner. Duncan further states:

> The resulting differences between how learners with different styles prefer to learn are startling. Kolb has stressed that the various learning styles are not traits, but staits. These *staits* are influenced significantly by past experiences, habits, and, most strongly, by current situational-specific demands. The important point is that one's style should be fluid, changing to meet current situational demands. Most adults, however, come to rely primarily on one style. (p. 59)

Nixon (2004) explored the processing and learning as a function of the brain, specifically, how each hemisphere of the brain perceives and processes information. According to his findings, "One concept of learning deals with the side of the brain that predominantly perceives and processes information…the left sees things analytically and verbally; the right perceives things visually and perceptually" (Nixon, p. 34).

Further research introduced the concept of motivation to the learning process. A differing viewpoint than that of Kolb was presented by Wilson (2000), including behaviorism, gestalt, cognitive theory and humanist theory. Wilson (2000) states:

> We learn through a complex interaction of reading, cognitive process, experience and what were are told or see. Some prefer to try out new process (hands-on training), some prefer to read and assimilate knowledge, thinking about the processes and identifying the problems in a conceptual manner; others will prefer a mix of both these processes. (p. 105)

In addition he identified five views concerning the manner in which people learn: 1) behaviorism, 2) neo-behaviorism, 3) gestalt, 4) cognitive theory and 5) humanist theory (Wilson, 2000). The first type, behaviorism, is based on stimuli-response theory.

A certain action (stimuli) results in another action (response). It is used to train animals and is, many times, followed by a reward for the correct action.

Neo-behaviorism is the response to an action from the conditioned response to a response linked to thought. That is, the response to stimuli must have a real purpose in the person's mind; it's not a reflex action, but an action which is taken for some given end.

The third type identified by Wilson is gestalt, which is the term used to describe the notion that the whole is bigger than its parts. See Figure 3: in the upper left-hand of the figure are three circles with a piece missing from each. Taken separately, that is exactly what they are; however, positioned as they are in the figure, one perceives a pyramid in the middle. Visual learners will immediately discern this shape. Similarly, just below the pyramid, one can see a set of cones depicted of different sizes and directions. The visual learner will immediately see the sphere that is implied by the orientation and dimension of the cones. The two others appear to be a vertically-oriented rectangle and, perhaps a serpent with half of its body below water.

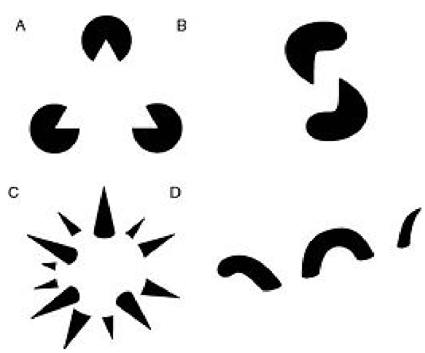

Figure 3. The Whole is Better Than Its Parts (From *Wikipedia*, n.d.)

Wilson's cognitive theory is exactly opposite of behaviorism. It assumes that individuals are logical in the thinking process and, rather than a conditioned or reflex, response, an action taken after a stimulus will be the action that makes the most sense to the individual. Finally, humanist theory espouses that decisions are not only based on cognitive thoughts but also on an evaluation of what is best for the individual.

As one explores these concepts, one can find evidence of these theories in our own lives; behaviorism, for instance, is the repeated actions following stimuli. For instance, simply watch how many people interrupt, almost automatically, whatever they are doing in order to read an email on their Blackberry®. The Blackberry® vibrates (stimuli) and the person reaches for it to read the text (action). It is a conditioned response, having been learned and repeated countless times.

Neo-behaviorism is a "new" angle on how one learns. It differs from behaviorism by introducing a thinking process into the mix. Although it is still a response to stimuli, there must be rationale behind the reaction. This is common in adult learners, who want to know why they need to learn, not just absorb facts for the purpose of absorbing facts.

A community, and its vulnerabilities, are a result of many interactions and relationships. Its physical location (coastline, inland, etc.), its make-up (residential, commercial, industrial), its demographics (aging population, affluent or not so affluent), and its infrastructure (utilities, roadways, etc.) all contribute to the entirety of the community. This is the gestalt theory in practice, the whole is greater than its individual parts. Those learners who subscribe to this theory can easily understand the sometimes fragile correlation between the community and that which threatens it.

Humanist theory recognizes both sides of the brain; it believes that the cognitive, logical side of the brain is not the only method of processing information but that the emotional side of the brain will filter the decisions of the logical side and develop decisions that make the most sense to the individual. Therein, however, lays the trap. Emergency managers and those presenting hazard vulnerability assessments to decision makers must assure that that "which makes the most sense" to an individual is also best for the community as a whole.

The emergency management community, including senior level emergency managers, municipal department heads, city managers and the elected officials who make decisions about budgetary requests from their staffs, need access to information about hazard vulnerabilities that is presented in a manner that depicts the relationships between particular communities and those possible catastrophic events to which it is vulnerable.

Reports, studies, assessments and plans used to communicate hazard vulnerabilities are all written for the purpose of conveying information to the emergency management community, but they are often presented using media that may not facilitate effective and efficient assimilation of that information for use in the decision-making process. Effectiveness in this context can be defined as whether or not the information was sufficiently understood in order to take appropriate actions regarding the specific vulnerability; efficiency can be defined as a function of the amount of effort needed to sufficiently understand the nuances of the specific vulnerability. As such, there appears to be a gap between these subjects. The purpose of this paper is to bridge that gap; to provide planners an insight into learning styles and how their understanding can be used to view vulnerability and how technology can be used quantify vulnerabilities and to improve the learning processes of individuals who make decisions based on these vulnerability reports.

C. HOW CAN TECHNOLOGY BE LEVERAGED TO INCREASE COMMUNITY HAZARD VULNERABILITY ASSESSMENT ASSIMILATION EFFECTIVENESS?

A number of technologically advanced tools are at an emergency manager's disposal. They can be used individually, or in conjunction, to present the relationships between the threats and those that are threatened. Leveraging technology, especially technology that takes advantage of graphic representation of data, will become more important as both the hazards that face communities evolve and as technology itself evolves. Community hazard vulnerability assessments must depict the threat in relation to the threatened. One such technology, geographic information systems, can be linked with modeling technology, such as, computer aided management of emergency operations (CAMEO), Hazard U.S. (HAZUS) and the infrastructure consequence flood inundation tool. As technology improves, other software programs will undoubtedly be developed. The emergency management community must keep up to date on these emerging tools.

1. Geographic Information Systems

Geographic information systems are, essentially, electronic maps. These systems, however, are more than just lines depicting roadways and other features; they can be made interactive, allowing the user to assimilate large amounts of information about specific topics. In a book concerning geographic information systems, written by the Digital Equipment Corporation (1991), Freeman is quoted as stating:

> Despite my many years in county government, I have never become accustomed to the lack of information available to make decisions. I have concluded that most poor decisions in government are due to lack of information or the inability to integrate many sources of information. (p. 2)[2]

Information regarding community hazard vulnerability assessments is plentiful and varied. In light of Freeman's comments, that "the inability to integrate many sources of information" (Digital Equipment Corporation, 1991), such assessments must be presented in manner conducive to the integration of raw data into information from which appropriate decisions can be made. These decisions include mitigation and response strategies to any particular community vulnerability. It is important that varying sources of information be integrated into the map such that the presentation of the information will facilitate the decision maker's needs.

Open the phone book and one will most likely find one of the oldest forms of communication in the world, the ubiquitous map. It might show local road networks, public transportation routes and, in areas proximate to nuclear power plants or the sea coast, evacuation routes. Of such importance are maps that, according to Haeber (2003), the United States Library of Congress spent 10 million dollars for the oldest known map marked "America." This map was apparently based on the data accumulated by Italian explorer Amerigo Vespucci during his voyage of 1501. The map, dated 1507, was discovered in 1901 and was described by the Chief of Geography and Map Division of the Library of Congress as "one of the great finds of the modern age."

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[2] Freeman was the County Executive for Harford County, Maryland.

But by no means is this map even close to being the oldest map known to man. Govan (2009) reported the oldest map known map found in San Gregorio, Spain as being about 14,000 years old. It took 15 years to decipher it, but "furthers understanding of early modern human capacities of spatial awareness, planning and organized hunting" (Govan, p. 14). It shows topographic features such as mountains and rivers in addition to locations to find food and hunting grounds.

Twenty years ago, the planning department of a city might have the basic street map, derived from various development plans; a zoning map, derived from legislation defining land use and a parcel map showing property boundaries within the municipality. The development plans in the planning department will detail the roadway network for that particular neighborhood including information on roadway widths and turning radii. The water department would possess maps showing the location and size of water mains and the location of valves and fire hydrants. In addition, the electric utility would have maps of their various distribution grids, depicting lines, voltages, breakers and switches, while the sewer department would have maps showing size and locations of sanitary and storm water lines.

Across the various levels of government and private companies, thousands of maps could be described, each having information that is useful to the other entities. Each of those maps might have been drawn at a different scale with different symbols illustrating different features; put all of that data on one piece of paper, a very large map, and confusion would reign. Nonetheless, the relationships between the data are important. For instance, which electrical substations are located within the one percent (formerly known as the 100-year) flood plain; or if a hazardous material spill occurs on a highway and enters into a storm inlet, where does that spill end-up? Such examples are countless and are limited only by the imagination. Attempting to show all of this information on one document would result in an unreadable map.

A number of technologies, either stand-alone or used in conjunction with each other, can enhance the comprehension of information by matching the learning styles of individuals, especially the visual learner. One such technology, geographic information systems, is especially appropriate for community hazard vulnerability assessments.

Spatial awareness, the importance of the relationship of data, is paramount and geographic information technologies permit the seamless integration of various data in a visual format. Harrison et al. (2006) stated:

> Of the various waves of technology development that has diffused widely over the last 3 decades, among the most exciting have been the tools that use or generate geo-spatial data, that is, data providing location information in which a common spatial coordinate system is the primary means of reference.

For instance, various risk institutions could simply be listed in a table showing their locations by address (Figure 4):

Day Care / Nursery School				
Adult Institutions		Listed Alphabetically By Name		
Private School				
Group Home		Location		
Name	**Type**	**Address**	**Latitude**	**Longitude**
Anderson Daycare	day care	178 Ross Road	40 06.074'	075 21.838'
Arden Courts	Alzheimer's facility	620 W. Valley Forge Road	40 06.314'	075 23.630'
Armenian Sisters Academy	Private School	440 Upper Gulph Road	40 03.713'	075 21.189'
Bright Horizons	day care	3200 Horizon Drive # 110	40 05.233'	075 20.362'
Salvation Army	Group Home	436 Fletcher	40 04.308'	075 23.391'
Devereux	group home	250 Hughes Road		
Footsteps Academy	nursery school	150 E. Beidler Road	40 06.781'	075 22.496'
For Kids Sake Childcare	day care	486 Keebler	40 05.933'	075 23.109'
Goddard School	day care	489 S. Gulph Road	40 04.623'	075 21.734'
Good Shepherd Church	nursery school	132 E. Valley Forge Road	40 06.173'	075 22.149'
Happ Enterprises	Group Home	554 Dartmouth	40 06.433'	075 22.300'
Heschl Day Care	day care	334 Coates St.		
Horizon Health Services	Group Home	1227 Rebel Hill Rd	40 03.867'	075 19.987'
Imagination Station	day care	111 E. Matsonford Road	40 03.676'	075 20.225'
Kinder care - Henderson Road	day care	211 North Henderson Road	40 05.830'	075 21.976'
Kinder care - Gulph Mills (old Mulberry)	day care	2001 Renaissance Blvd.	40 04.987'	075 20.034'
Malvern School	day care	747 S. Gulph Rd	40 04.541'	075 21.223'
Manor Care	nursing center	600 W. Valley Forge Road	40 06.219'	075 23.579'
Margaret George School	nursery school	491 Allendale Road, Suite 210	40 05.779'	075 23.569'
Miller Daycare	day care	232 Colmar Dr.		
Mother of Divine Providence School	elementary school	405 Allendale Road	40 05.634'	075 20.480'
Toddler Town Learning Center	day care	650 S. Henderson Road	40 04.761'	075 21.051
Temple Brith Achim	Private School	481 S. Gulph Road	40 06.618'	075 21.797'
Trinity Nursery & Kindergarten	nursery school	966 Trinity Lane	40 04.256'	075 20.480'
Upper Merion Baptist Nursery	nursery school	585 General Stuben	40 06.080'	075 23.499'
Valley Forge Presbyterian	nursery school	191 Town Center Road	40 05.766'	075 22.165'

Figure 4. Risk Institutions by Address (From Upper Merion Township, 2012)

Utilizing the capabilities of a geographic information system, these same facilities can be plotted on a map depicting their location on a map (Figure 5):

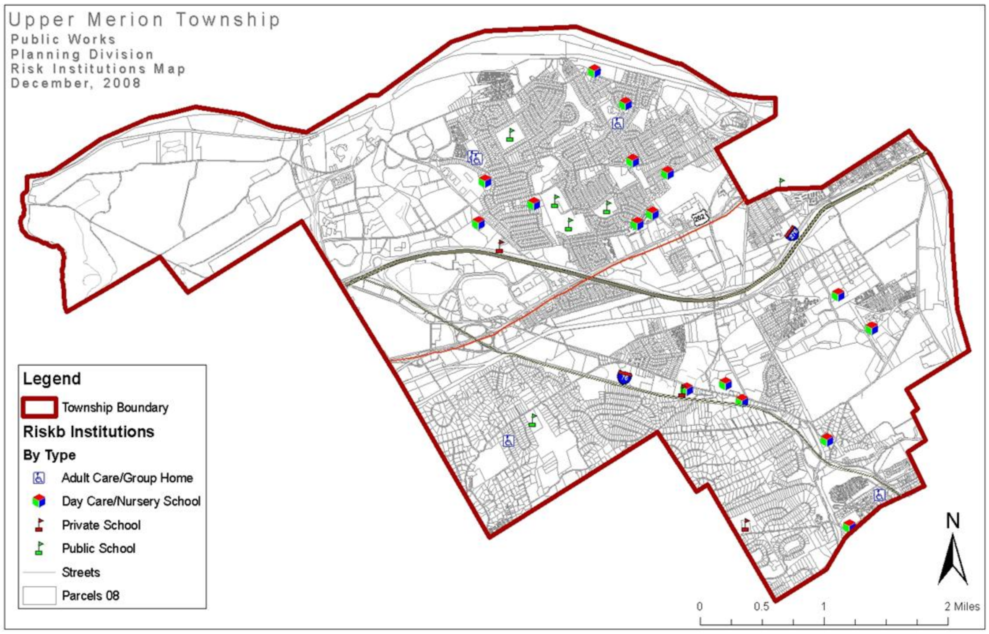

Figure 5. Risk Institutions by Map (From Upper Merion Township, 2012)

The visual leaner, by his or her nature, will most likely prefer the map depiction, but the real advantage of geographic information systems is the ability to illustrate the spatial relationships between the threat and the threatened. Figure 5 is a map layer depicting a number of risk institutions, additional layers of toxic chemical plants, dams, levees, flood plains and inundation maps can be created also layered on the map to show the proximity of those facilities with each other. Beckman and Simpson (2006) describe geographic information systems as a tool for vulnerability assessments as "…enabling the processing of complex geospatial data sets with respect to the assessment of vulnerabilities and the risk from various hazards" (p. 409).

Geographic information systems allow the visualization of data. According to Nixon (2004) and Rostan (2003), such visualization enhances the ability to comprehend vast amounts of information. In addition, and probably more importantly, this ability to image narrative data provides a platform to understand not only the raw data but also the

relationships among that data; this results in usable, actionable information. A geographic information system (GIS) can unravel this confusion, as it can “layer” the data for specific purposes. The concept of layering is shown in Figure 6, which shows eight layers, including topographic information, parcels, zoning, floodplains, wetlands, land cover, soils, etc. Each of these layers can be switched on or off, depending on the needs of the user.

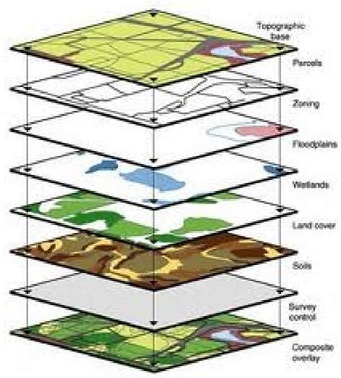

Figure 6. Layering Concept for Geographic Information Systems (From Google, n.d.)

According to Cahan and Ball (2002), the foundation of a geographic information system used to support emergency operations at the World Trade Center attack site was the base map: “Without the base map, no common framework would have existed to so quickly tie together the essential information used to coordinate the city’s response.”

The historical importance of maps has been previously discussed. To understand the ability of a geographic information system to co-relate data among databases, the following depictions are offered, all from Upper Merion Township’s *Emergency Operations Plan* (2010). Figure 7 depicts the base map and includes the street, parcel outlines and building outlines.

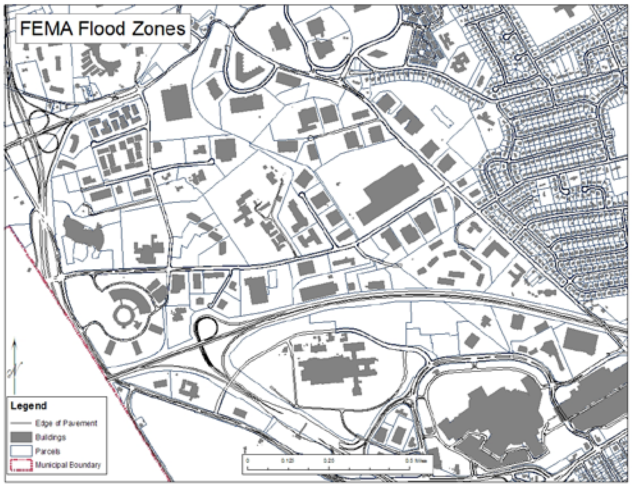

Figure 7. Base Map (From Upper Merion Township, 2010)

This is adequate for finding the way from point “a” to point “b,” the normal use for a map, but if one if looking for more information, say, the hydrography of the area, the geographic information system might have such a layer. If so, that layer can be overlaid on top of the base map, resulting in Figure 8.

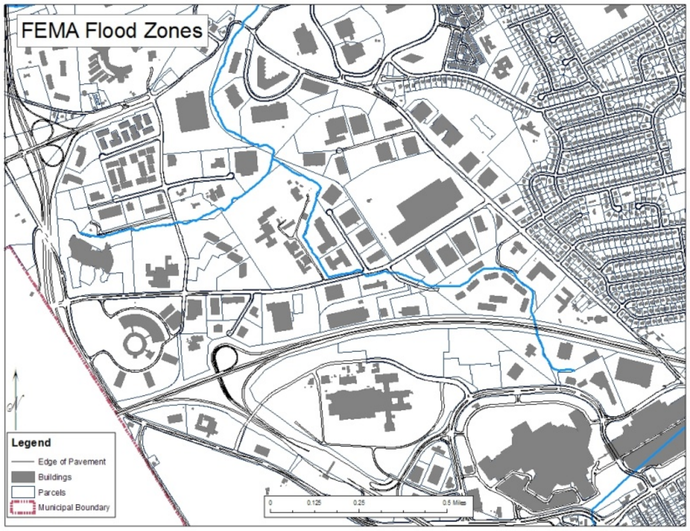

Figure 8. Base Map Plus Hydrography (From Upper Merion Township, 2010)

The blue lines in Figures 8 and 9 show the geospatial information regarding the streams that flow through the area of the map. This information is geocoded to predetermined reference points to assure the correct location on the map.

Geographic information systems also permit the overlay of “orthoimagery.” Such imagery has as its basis an aerial photograph. This photograph is then manipulated such that the image has no distortions caused by camera angle. In addition, the photo is then corrected and sized to meet the scale of the map to which it might be overlaid. This process is called “rectifying” the image. A rectified orthographic image that depicts the hydrographic information displayed in Figure 8 is displayed as Figure 9.

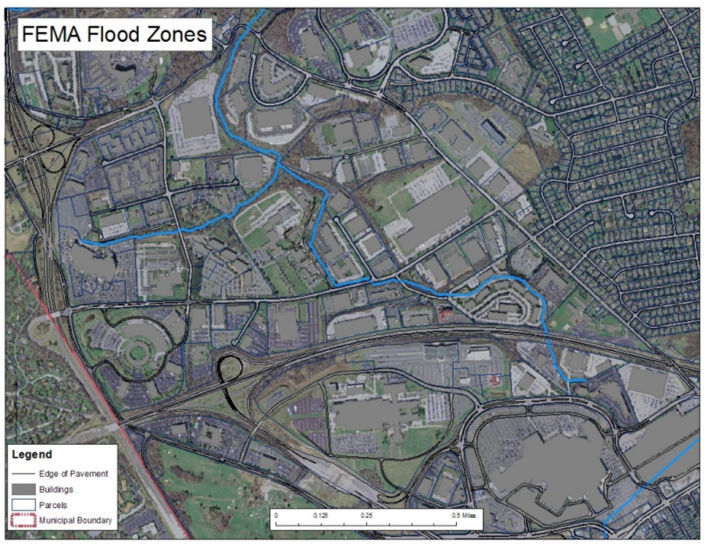

Figure 9. Orthographic with Hydrography (From Upper Merion Township, 2010)

Figure 10 then expands on the orthographic image shown in Figure 9. City planners, emergency managers and, hopefully, individual property owners should be concerned about flooding. The Federal Emergency Management Agency produces maps that show the “100-year flood plain.” Such information can also be loaded as a layer in a geographic information system database. Such a map would represent the flood plains thusly (Figure 10):

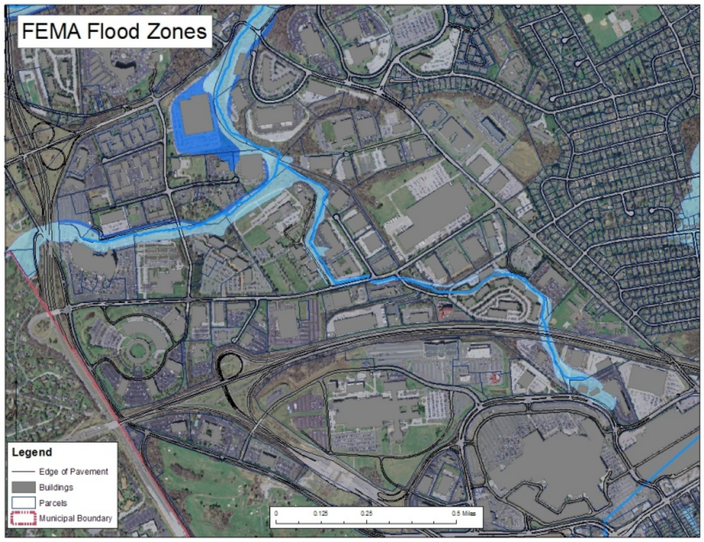

Figure 10. Orthographic with Flood Plain (From Upper Merion Township, 2010)

The system can then be instructed to determine all of the parcels that are "touched" by the floodplain, resulting in the following map (Figure 11).

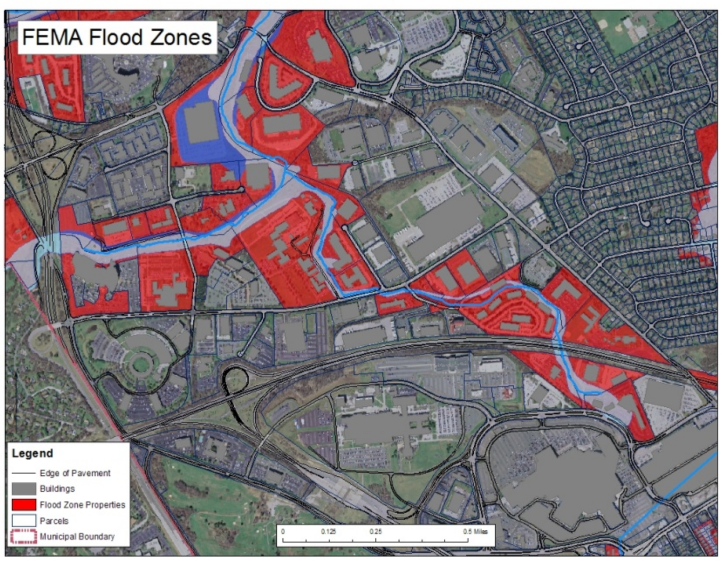

Figure 11. Orthographic Depicting All Parcels Touched by the Flood Plain (From Upper Merion Township, 2010)

Geographic data can then be compared with specific locations, such as risk institutions; for instance (Figure 12):

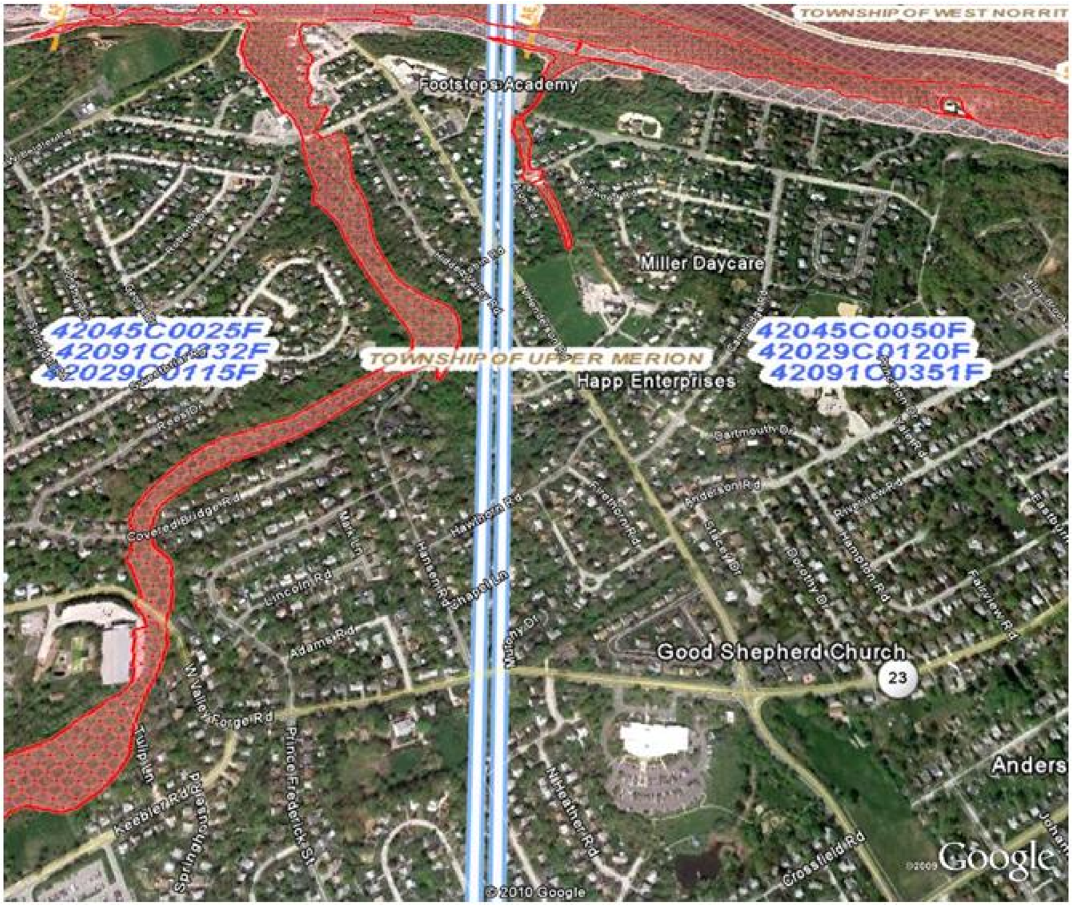

Figure 12. Geo-coded Floodplain and Risk Institutions (From Upper Merion Township, 2010)

In a narrative, the above information would read:

> The floodplain extends from 10 to 50 feet back from the edge of Crow Creek's normal channel. Miller Day Care is located 232 Colmar Drive; Happ Enterprises, a group home, is located at 554 Dartmouth Drive Road and the Good Shepherd Church is located at the intersection of Henderson and Valley Forge Roads.

All of that information is readily available at one glance of a map. One does not have to ask the proximity of the addresses to a floodplain because it is visually displayed. In addition, it is possible to put a mouse over the name of the facility in question and have detailed information be displayed immediately.

Future GIS systems could be tied to sensors, providing real-time hazard assessments. For instance, the Advanced Hydrologic Prediction Service of the National

Weather Service maintains 4521 river gauges (National Weather Service, n.d.). During times of heavy precipitation, their prediction service provides estimates of the height of the river that can easily be converted to height above mean sea level (see Figure 13)

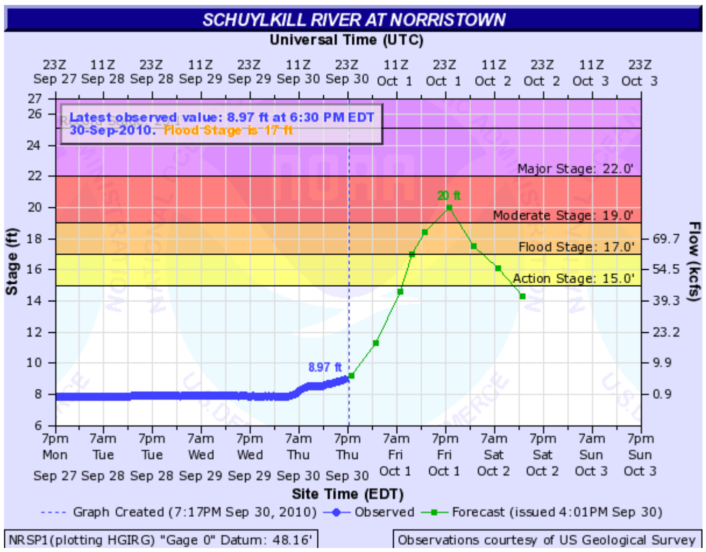

Figure 13. Flood Gauge at Norristown, PA (From National Weather Service, 2013)

One only needs to determine the height above mean sea level of the gauge itself. In the example provided, the gauge is at 50’ above sea level. Therefore, the 20’ level of the gauge is 70’ above mean sea level. A geographic information system could create a map showing all areas of the municipality below 70’ above sea level, thereby illustrating the zone of concern.

Sensors that provide elevation data could be linked to a geographic information system to provide early warning of flooding *hours* prior to that flooding. For instance, Figure 14, created at 1917 hours on 30 September, depicts moderate flooding predicted at 1900 hours on 01 October. This would provide a 12-hour window to evacuate an area, move equipment and close roadways *before* the problem actually occurs.

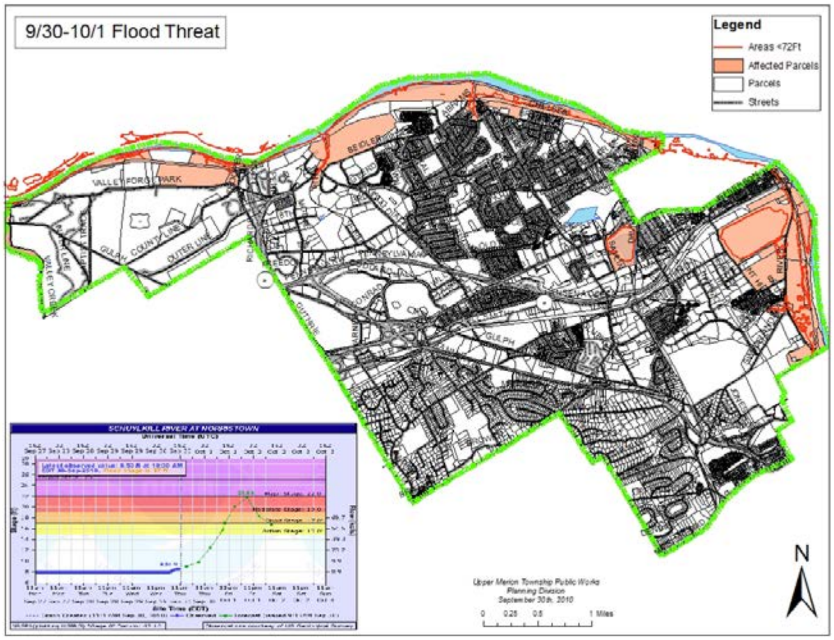

Figure 14. Upper Merion Township-area <72' mean sea level (After National Weather Service, n.d.)

Geographic information systems are not perfect. Many have heard the adage, "junk in-junk out"—as it is with all information systems, whether paper or electronic, the value of the data is only as good as its original validity. That is, errors in entering data will compromise its worth. However, making changes in electronic systems is more efficient than having to recall all paper reports in order to change bad data. Such GIS systems, however "…enable greater understanding of natural systems by abstracting aspects of the world into knowledge object—data, imagery, models, and maps—that form a systematic framework for a collective understanding that is the basis for intelligent action" (Dangermond, 2012, p. 10).

2. CAMEO

Computer-Aided Management of Emergency Operations (CAMEO) was developed by the National Oceanic and Atmospheric Administration; CAMEO is a "Computerized emergency and chemical information data system…available to provide…vital information even before the response team gets to the hazardous material

spill" (Snider & Jover, 1989, p. 20). According to its user manual (U. S. Environmental Protection Agency & National Oceanic and Atmospheric Administration, 2010):

> CAMEO was developed because NOAA recognized the need to assist first responders with easily accessible and accurate response information. Since 1988, NOAA and EPA have collaborated to further the development of CAMEO. The U.S. Census Bureau and the U.S. Coast Guard have also worked with EPA and NOAA to enhance CAMEO.

Initially used during the early stages of an emergency by hazardous materials response teams, CAMEO can also be used to visualize the impact of a chemical release prior to the release actually occurring. CAMEO includes a plume modeling software that takes the physical data associated with a hazardous chemical, including vapor pressure, vapor density, toxicity data and flammability protocols and can create a visual depiction of the vulnerability zone. The user identifies the chemical from CAMEO's database and then enters the location of the event and the current weather conditions, including temperature, relative humidity, wind speed and direction. The software then creates a polygon showing the areas of concern, identified by the user. The display can give a picture of the toxicity, such as levels immediately dangerous to life and health (IDLH) and the threshold limit value (TLV). Or, if the user desires, the display can give a picture of the areas by flammable limits (too rich, stochiometric, or to lean).

CAMEO utilizes a mapping protocol called Mapping Application for Response, Planning and Local Operational Tasks (MARPLOT), coupled with a dispersal modeling protocol called Area Locations of Hazardous Atmospheres (ALOHA). Coupled with the geographic information system, the plume can be overlaid as a layer and the user can then toggle-on or toggle-off the other layers, such as schools, hospitals, nursing homes and the like (see Figure 15). The spatial relationship of a possible hazardous release can then be understood and the vulnerabilities explored. This type of system fits the learning styles of both the visual learners and the kinetic learners.

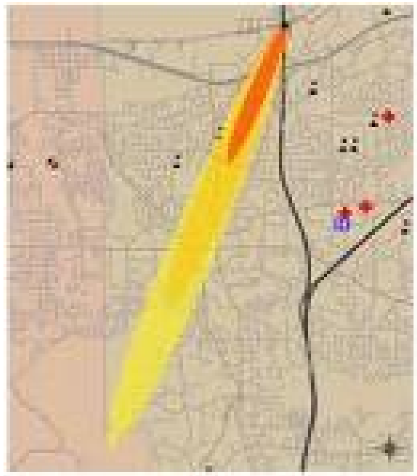

Figure 15. Plume Model Result from CAMEO (From *Wikipedia*, n.d.)

In this manner, the vulnerability of a community to such a release can be anticipated, understood and planned for. According to Schellenbarger (2003), “Risk and vulnerable areas can be identified to determine proper emergency response procedures and assist in community planning in the event of a disaster” (p. 10).

Developed in the early 1980s, CAMEO has evolved over the years. Fekete (1991) wrote, “The early versions were primarily an emergency response tool with limited planning capability, a far cry from the multi-function program CAMEO has become” (p. 76). The *Superfund Amendments and Reauthorization Act* (SARA Title III) requires that certain facilities that store or use extremely hazardous substances develop a plan for the unplanned release of such substances. Included in the plans are “vulnerability zones.” Utilizing CAMEO and visualizing the size of some of these vulnerability zones “…amazes industrial facility management personnel and, as a direct result, several plants have substituted non-extremely hazardous chemicals for extremely hazardous chemicals” (Fekete, 1991, p. 76).

3. HAZUS

Hazards United States-Multi-Hazard (HAZUS-MH) was developed in the mid-1990s as a collaborative effort between the Federal Emergency Management Agency and the National Institute of Building Sciences. Coupled with ESRI’s ArcGIS, “HAZUS is designed to assist communities with natural hazards planning and response, including

periods before, during and after a disaster" (Beckman & Simpson, 2006, p. 411). Although HAZUS itself is available through the Federal Emergency Management Agency free of charge, the platform needed to run it, ArcGIS is not. ArcGIS and the needed extension, spatial analysis, are available from the Environmental Systems Research Institute (ESRI) of Redlands, CA.

Van der Heihden (2005) proposes that strategic conversations center around "what-if" thought processes, not only examining the environment in which decisions are made by competitors, but actually studying the decision makers, using "…the scenario process to…look at the people behind the decisions, not just the technical or macro phenomena" (p. 5). Plume modeling, flood inundation modeling and disaster simulation modeling could all be used to conduct scenario-based hazard assessments. These scenarios, saved as data files, could be retrieved at the time of the actual event to aid in the response. For instance, flood inundation maps showing dam failure at maximum probable flood could be reviewed prior to the hit of a hurricane, providing planners the information and time needed to plan for the response and evacuate those threatened.

HAZUS-MH currently has the capability to model earthquakes, floods and hurricanes, providing geospatial graphics of loss probabilities for the visual learner, as well as statistical tables of loss for those who prefer hard numbers. It can generate probabilistic damage assessments to buildings and infrastructure, estimates of deaths and injuries and probable number of displaced families, resulting in an approximation of shelter needs and a rough calculation of debris tonnage. Bouabid and Caplan (2004) state, "FEMA recommends using HAZUS-MH in the risk assessment studies required by the Disaster Mitigation Act of 2000" (p. 15).

HAZUS-MH is not perfect and has shown some data inaccuracy; FEMA is constantly tweaking the program to make it better. For instance, according to Vickery, Lin, Skerlj, Twisdale and Huang (2006), HAZUS-MH:

> …has been updated to include all historical storms in the Atlantic Basin for the period 1886–2001…and the model has been revalidated through comparisons of the statistics of key hurricane parameters along the Gulf and Atlantic States derived from both the historical data and the model simulation results. (p. 83)

Vickery et al. (2006) report, “The damage model has been validated, wherever possible, through comparisons of modeled damage to observation from poststorm (sic) damage studies” (p. 103). Four validation studies were reported, each following a large storm, Andrew (1995), Hugo (1999), Erin (2001) and Opal (1995); it was reported, “…the loss validation studies have shown that the damage and loss models reproduce observed losses reasonably well” (Vickery et al., 2006,p. 101).

Research appears to indicate that how the information is presented is as important as the information itself. Resource allocation decisions should be free from ambiguity. The decisions made as a part of the study of a hazard vulnerability assessment need to be decisive. As such, it is important that the review of the information contained in the community hazard vulnerability assessment be lacking in that which Daft and Lengel. (1986), term equivocality. They define equivocality as “…the existence of multiple and conflicting interpretations about an organizational situation…high equivocality means confusion and lack of understanding” (Daft & Lengel, 1986, p. 556).

A lack of understanding of the vulnerabilities that face a community can result in disastrous decisions. Ollerenshaw et al. (1997) keenly observe, “Multimedia supplementation resulted in superior text comprehension, while standard diagrams did not improve comprehension over ‘text only’ condition” (p. 1). Furthermore, the case for computer modeling and presentation through geospatial representations is beneficial as “Computerized learning programs which communicate information using visual stimuli, have had similar levels of success. Such programs are believed to enhance the capacity for recall, recognition, comprehension and problem solving abilities” (Ollerenshaw et al., p. 1). They conclude by stating, “The overall results support the notion that textual learning is generally enhanced by computer simulated multimedia diagrams” (Ollerenshaw et al., p. 3).

Vulnerability = Risk x Consequences (V = R x C), but determining consequences is an attempt to predict the future. The reason behind conducting hazard vulnerability assessments is to plan. A newer modeling tool, HAZUS-MH (Hazard-U.S.—Multi-Hazard), permits planners to have a glimpse into the future. Brown (2001) puts it quite

succinctly, stating, “Without HAZUS, it becomes very difficult to effectively complete the risk assessment required for …planning” (p. 6).

HAZUS takes its raw data from the data submitted to the Census Bureau. All of the algorithms regarding consequences are measured by census tract. It is both appealing to the visual learner and the kinetic (tactile) learner. The user variables are 1) location, 2) the type of event and 3) the magnitude of the event. The results are calculated; that is, there are no emotional decisions involved. The computer does the work and displays it as color coded census tracts or landmarks. Rich Davies (2011), the Executive Director of HAZUS.org, provided the following examples (Figures 16–18) of outputs from the HAZUS software after modeling an earthquake equal to the 1906 San Francisco disaster. Such outputs include:

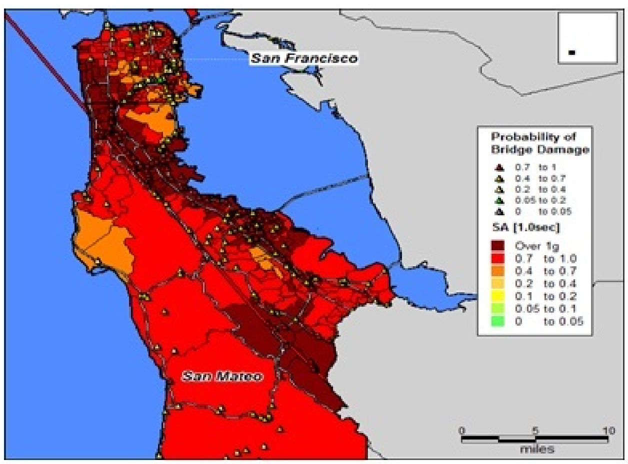

Figure 16. Bridge Damage for San Francisco Peninsula (From Davies, 2011)

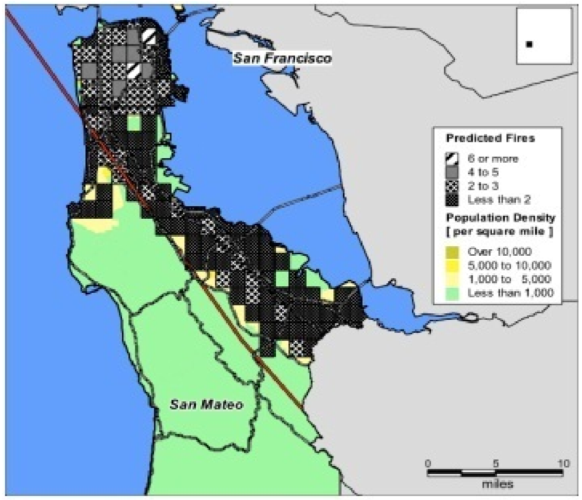

Figure 17. Fire Ignitions (From Davies, 2011)

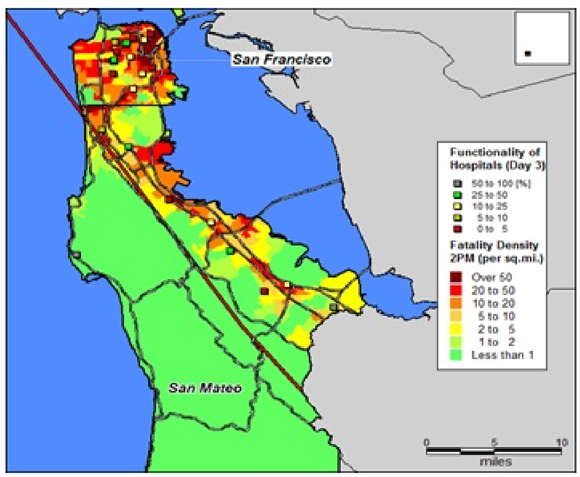

Figure 18. Hospital Functionality and Fatality Density (From Davies, 2011)

After a disaster, when all of the trapped have been rescued, the fires extinguished, the injured treated and the dead buried, the task of housing the displaced and cleaning-up the debris remains. HAZUS-MH also includes an algorithm for calculating the number of households displaced and the demand for shelter. Hazard vulnerability assessments must also include plans for debris management. Present-day San Francisco, if it experiences a 1906 replica earthquake, can plan for a massive clean-up effort. Through the wizardry of technology, it can be predicted (Figures 19–21):

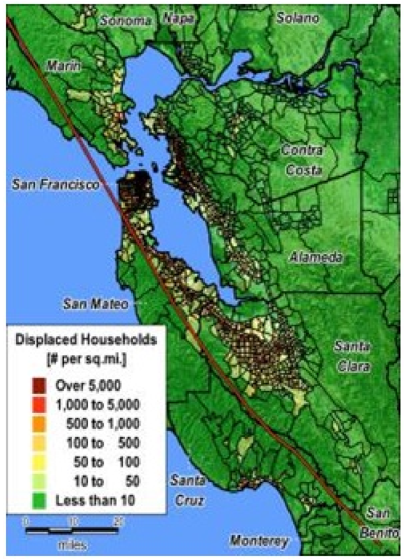

Figure 19. Households Displaced (From Davies, 2011)

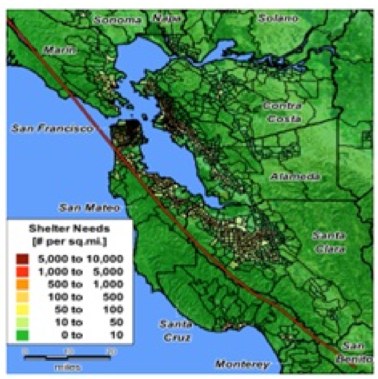

Figure 20. Shelter Demand (From Davies, 2011)

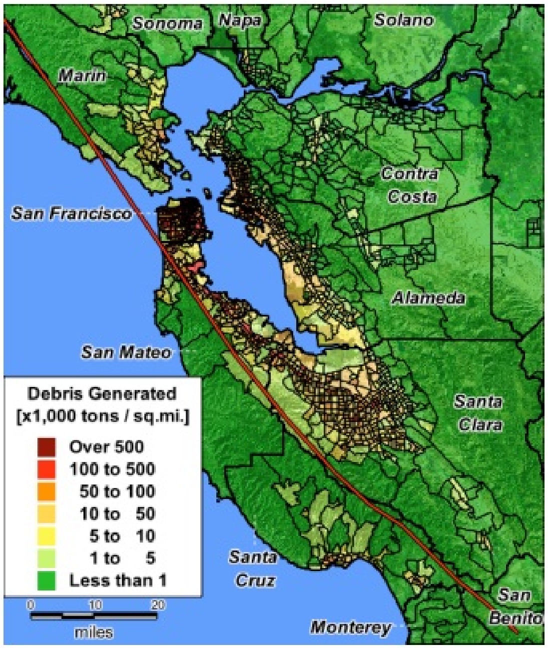

Figure 21. Debris Generated per Square Mile (From Davies, 2011)

4. Infrastructure Consequence Flood Inundation Tool-2D

Larson, Del Valle, Ambrosiano, and McPherson (2011) observed, "The ability to realistically simulate and predict the cascading impacts from an adverse event or disaster is key to characterizing its risk. It can also help with emergency planning, mitigation and resource allocation before and after the event" (p. 26). To that end, the Los Alamos National Laboratory, Energy and Infrastructure Analysis Group developed the Infrastructure Consequence Flood Inundation Tool-2D. The is software expanded on the work of Penning-Rowsell, Flood, Ramsbottom and Surendran (2005), who used three factors in estimating injury and loss of life: flood hazard, area vulnerability and people vulnerability. Their algorithm is displayed in Figure 22.

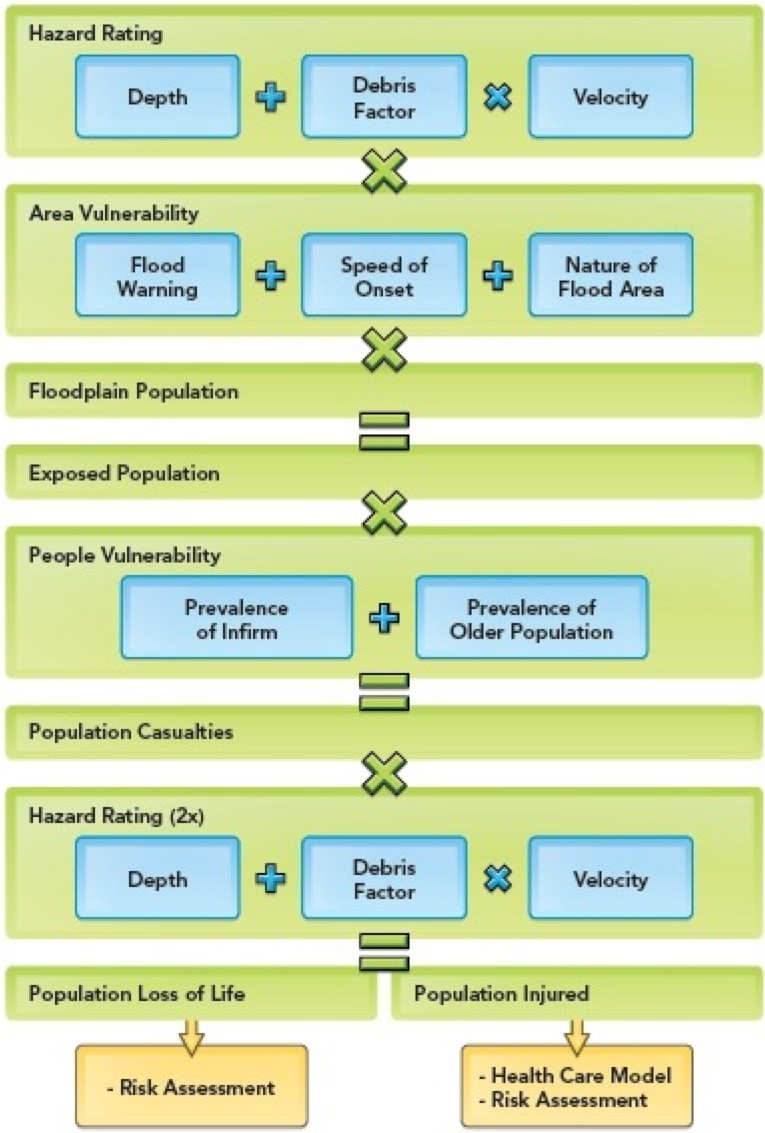

Figure 22. Methodology or Determining Consequences (From Penning-Rowsell et al., 2005)

The Infrastructure Consequence Flood Inundation Tool- 2D (ICFIT-2D) is a "new GIS-based tool to qualify and quantify the risk and impact of flooding on the health care sector" (Larson et al., 2011, p. 22). Its purpose is to determine the vulnerability of the population to flooding events and predict the needed surge capacity of the local health-care system to handle the influx of injured and dead. Flood plain maps display where the water might be; the ICFIT-2D not only predicts where the inundation limits will be, but also shows the depth of the water over an area (see Figure 23).

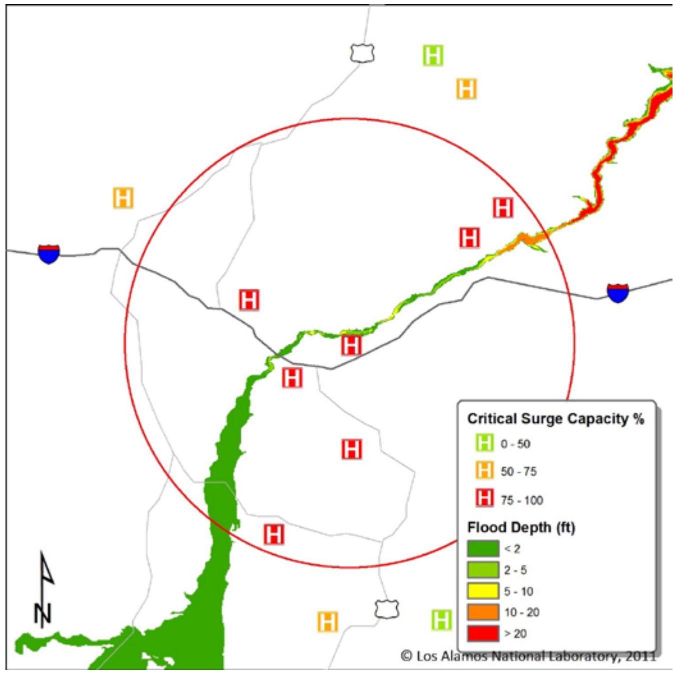

Figure 23. Flood Depth and Hospital Surge Capacity Needed (From Davies, 2011)

V. RECOMMENDATIONS AND CONCLUSIONS

A hazard vulnerability assessment, to determine the risks to which a community is exposed, is not only useful, it is required by the *Federal Disaster Mitigation Act of 2000*. In order for communities to be eligible for various disaster reimbursements from the Federal Emergency Management Agency, communities must be in compliance with this federal statute. States may recommend updating, as the Pennsylvania Emergency Management Agency does every five years. It is an updated hazard vulnerability assessment that demonstrates to the community to where resources for planning and operations should be allocated.

In order for funds to be allocated on a priority (risk-based) basis, it is important that decision makers, our elected and appointed officials, fully comprehend the contents of a community hazard vulnerability report. Simple narratives should not be the only method used to convey such information. Different people assimilate data in different manners; how the information is presented is as important as the information itself. Hazard vulnerability assessments and reports must be customized to how people learn and, as such, the study of how people learn is important in the community emergency preparation and response field.

Technology, especially GIS and its peripheral software, can address a number of problems; not the least of which is validity. Ongoing changes within the community can be documented in a timely manner, keeping the information from becoming stale or outright useless; modeling can provide a glimpse into the future, allowing "what-if" scenarios to be tested; in addition, modeling can provide some guidance as to the magnitude of a given scenario, providing both casualty and damage estimates.

As such, the following points and recommendations are made, fully realizing that further research into new technologies and software packages should be ongoing.

1. Communities conduct hazard vulnerability assessments to provide a basis for risk-based resource allocation decisions. As such, such assessments must be timely and accurate. Old data is of limited value; vulnerability studies must be dynamic and change at the pace the community changes. The Delaware County assessment referenced earlier in this thesis clearly

shows how a decision maker’s resource allocation priorities could be skewed as there are vulnerabilities listed in the report that no longer exists and new vulnerabilities that have yet to be identified. Validity is paramount; hazard vulnerability assessments need not only include data, but data that is up-to-date.

2. In order for community hazard vulnerability assessment to be timely and accurate, the use of paper reports should be limited. Data should be stored in easily changed databases. Linked to recommendation 1, the data found in paper reports begins to lose its value once the paper leaves the printer; they older they get the less value they have. Electronic databases can be updated literally by the minute. Data entered in these databases can keep pace with changes as changes occur. The only limitation is the access. This “limitation” is both a strength and weakness. Electronic databases stored on private servers can only be accessed if the user is connected to those servers; similarly, databases stored in “the cloud” can only be accessed if the user has Internet capability. These issues are not insurmountable, but need to be addressed.

3. Humans process information in a number of ways and, although narratives provide good background, large quantities of information can be effectively communicated using maps, charts and tables. It has been said the pictures are worth a thousand words. For the purpose of this paper, let us replace the concept of “pictures” with graphics. Hansen (n.d.) reported that 60 percent of people are visual learners; color-coded charts, electronic maps with overlays, photographs and graphs representing raw numbers provide the visual learners the learning environment in which they comprehend best.

4. Technology can be leveraged to present much of the information found in community hazard vulnerability assessments graphically. The use of geographic information systems, and their attendant software add-ons, display information to provide a visual representation of the data that can intuitively show relationships (i.e., layers that show floodplains overlaid by layers that show critical infrastructure or health-care facilities). Geographic information systems ARE databases; possessing all of the advantages and disadvantages associated therewith. Information can be updated on a timely basis; the spatial relationship between the threat and that which is threatened is depicted visually. As communities grow and add or change street configurations, the geographic information system, and the meta-data contained within it, also grows. Validity is maintained.

Emergency managers must take full advantage of the technology available in conducting and maintaining a community hazard vulnerability assessment. Through visual depictions, an overall, fairly objective, estimation can be made of the

consequences of certain types of disasters. These approximations can be provided to decision makers in manners that appeal to the visual, auditory and kinetic learners.

Khan (2011) demonstrated in a TED.com presentation how a different method of educational methodology could enhance the learning process in schools:

> Let’s use video to reinvent education espouses the use of interactive technology to enhance learning. In it he shows the power of interactive exercises, and calls for teachers to consider flipping the traditional classroom script—give students video lectures to watch at home, and do ‘homework’ in the classroom with the teacher ready to help. (From Khan, 2011)

Enhancing learning through not only through video, but utilizing many types of technology, can assist in depicting the hazards that face a community. Narrative hazard vulnerability assessments, as mentioned previously, are a very archaic learning media. Information gleaned from these reports is used to make decisions on how we are going to prioritize our efforts to protect the public. By utilizing technology in the learning environment, students, and by that I mean the emergency management community, attempting to learn about the risks facing their community, can learn at their own pace with no fear of looking less than smart. Technology allows them to make mistakes in private and seek help only for the subjects that are troubling them. Khan (2011) gives an example of using such a system in teaching mathematics. He states, “The traditional model, it penalizes you for experimentation and failure, but does not expect mastery. We encourage you to experiment. We encourage you to fail. But we expect mastery” (Khan, 2011).

Emergency managers can, and should, “think out of the box;” they need to embrace technology as a tool to plan for the future, to embrace technology as a learning tool and to embrace technology as an integral part of the hazard vulnerability assessments.

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